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Dry matter intake, dry matter digestibility and growth performance in goats fed grass-based diet (*Brachiaria* or *Cenchrus*) compared with a concentrate-based diet

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Dry matter digestibility (DMD), dry matter intake (DMI) and growth performance of concentrate- and forage-based diets were investigated using 24 growing Blended goats (12 males, 12 females) weighing 16.5±1.2 kg (mean±sd). Goats were blocked by sex and assigned randomly to three dietary treatments that were fed for 10 weeks, after two weeks of adaptation. Dietary treatments were MRG (40% maize bran, 40% rice bran, 20% *Gliricidia* leaf meal), BG (80% *Brachiaria brizantha* cv. Piatã, 20% *Gliricidia* leaf meal) and CG (80% *Cenchrus ciliaris*, 20% *Gliricidia* leaf meal). All diets contained sufficient nutrients to meet the requirements of growing goats. The MRG diet had lower DMI than CG, likely because MRG had small particle size and goats adapted slowly to that diet. Average daily weight gain was 10.7, 9.9 and 22.8 g/day for MRG, BG, and CG respectively, and did not differ among the diets. Goats fed MRG had lower overall live weight change than goats fed CG, while goats fed BG were intermediate. These findings indicate that *B. brizantha* cv. Piatã and *C. ciliaris* are equally useful as supplementary feedstuffs for growing goats during the dry season.

Key words: *Brachiaria brizantha* cv. Piatã, *Cenchrus* ciliaris, maize bran, rice polish, *Gliricidia sepium*.

INTRODUCTION

Goats are an important livestock species in low-income countries, due to their relatively shorter generation interval and higher prolificacy than cattle and may improve the livelihoods of resource-poor farmers by ensuring food security and a steady source of income (Kosgey et al., 2008). However, as for all livestock production, goat

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production in the tropics and subtropics is constrained by seasonal variations in the quantity and quality of native forage species. During the dry season, goats in high-input (intensive) production systems may be fed concentrates, e.g. agriculture mill by-products as supplementary diet (Komwihangilo et al., 2005; Safari et al., 2009). These concentrates are expensive due to high demand from farmers rearing different livestock species, and large volumes are needed in extensive systems to feed large goat herds. Therefore, herders in extensive systems instead often opt to migrate in search for forage to alleviate dry season effects and ensure survival of their livestock (Butt et al., 2009; Treydte et al., 2017). Following recent changes in Tanzania human population, land uses and governance herder migration is increasingly limited (Mtimbanjayo and Sangeda, 2018), these necessitate a need to find cheap feedstuffs that can be used to maintain goat productivity in extensive livestock systems during the dry season. Also, free-browsing goats fed high concentrates diets during the dry season may need to adapt to change from their main forage diet by altering rumen microbiota and metabolism which can affect growth performance and health (Sun et al., 2010; Hua et al., 2017). Forage-based diets are better suited as alternative cheap feeds and can maintain production and intake, especially in free-browsing goats.

Grass species like *Cenchrus ciliaris* (buffel grass) have potential as a supplementary feed for goats due to high yield, good nutritional value and drought resilience (Santos et al., 2013; Patidar and Mathur, 2017). Biomass yield of *C. ciliaris* in semi-arid regions is 1.1-2.6 tonne dry matter (DM) per hectare and crude protein (CP) content is 49-99 g/kg DM (Bwire et al., 2003; Patidar and Mathur, 2017). Feeding *C. ciliaris*-based diets to goats can be a good option to alleviate feed shortage problems in the tropics, but reported performance results are inconsistent (Goromela et al., 1997; Komwihangilo et al., 2005). *Brachiaria brizantha* cv. Piatã (bread grass) bred in Brazil for high yield and drought resilience was introduced recently in Tanzania as a potential livestock forage (Santos et al., 2013). This cultivar gives biomass yield of 1.6-3.9 t DM/ha and the CP content ranges between 83 and 158 g/kg DM (Mutimura et al., 2018; Santos et al., 2018). There has been limited research on feeding *B. brizantha* cv. Piatã to goats, but a study on dairy cattle observed improved feed intake and weight compared with feeding other grasses (Mutimura et al., 2018). Adequate growth has also been reported in beef cattle grazed on *B. brizantha* cv. Piata (Santos et al., 2018).

This study evaluated DM digestibility, DM intake and growth performance in Tanzanian Blended goats fed a diet based on *B. brizantha*, *C. ciliaris* or concentrate (maize bran and rice polish, which was used as the standard dry season diet). The hypothesis tested was that adding *Brachiaria* and *Cenchrus*, rather than concentrates, to the diet of previously free-browsing goats increases feed intake and growth performance.

MATERIALS AND METHODS

Study site, animals and housing

Twenty-four (12 males and 12 females) growing Tanzanian dual-purpose Blended goats (55% Kamorai, 30% Boer, 15% Small East African goat) weighing 16.5±1.2 kg (mean±sd) were used in a feeding experiment run between December 2019 and February 2020. Prior to the experiment, the goats were browsing freely on semi-natural pasture at the Tanzania Livestock Research Institute (TALIRI) in Kongwa district (6°-6°6'S, 26°22'-36°30'E), Dodoma, central Tanzania. The district has a semi-arid climate and vegetation consisting of herbaceous layer dominated by *Cenchrus ciliaris*, *Cynodon* spp., *Chloris gayana*, *Urochloa mosambicensis* and *Aristida* spp. grasses and a shrub layer dominated by *Grewia bicolour*, *Acacia* spp. and *Commiphora eminii*.

Just before the experiment, the goats were individually housed in 1 m × 1 m elevated slatted pens (separated by wire mesh), dewormed using albendazole (oral dose 1 ml/25 kg body weight (BW)), Hebei Yuanzheng Pharm. Co. Ltd, China) and vaccinated against contiguous caprine pleuropneumonia (CCPP) and pest des petits ruminants (PPR). The goats were blocked by sex and randomly assigned to dietary treatments within blocks. Each dietary treatment was fed to eight goats (4 males, 4 females) for 10 weeks, preceded by a two-week adaptation period. During this adaptation period, goats in the concentrates group were given around 100 g *Cenchrus* hay for some days to help them transition from free browsing to the concentrate diet.

Diet formulation and feeding

The diets were expected to supply the estimated daily requirement in growing indigenous goats of 3.07 g/kg $BW^{0.75}$ metabolisable protein and 488.5 kJ/kg $BW^{0.75}$ metabolisable energy (ME) (Luo et al., 2004a, b). The dietary treatments were BG (80% *B. brizantha* cv. Piatã, 20% *Gliricidia* leaf meal), CG (80% *C. ciliaris*, 20% *Gliricidia* leaf meal) and MRG (40% maize bran, 40% rice bran, 20% *Gliricidia* leaf meal). The high bran amount (80%) included in MRG diet aimed to reflect nutrient dense fattening diet fed to growing crossbred goats (Mushi et al., 2009). The *B. brizantha* cv. Piatã and *C. ciliaris* materials used were harvested at the end of growing season (prior to glooming stage), on Magadu farm, Sokoine University of Agriculture (SUA), and TALIRI-Kongwa farm, respectively. In both cases, the aboveground plant parts were cut at ground level, sun-dried in the field to make hay and then chopped into small pieces (about 3 cm) using a mechanical chopper (Master 50, Penha Industria Brasileira®). *Gliricidia sepium* leaves were harvested on both farms and dried in the shade to make leaf meal, which was included in all diets as the protein source. Maize bran and rice polish were purchased from agricultural mills and mineral premix (calcium 240 g/kg, potassium 160 g/kg, phosphorus 150 g/kg, magnesium 12 g/kg, Vitamin D 1,500,000 I.U) from a farm-veterinary store. All dietary treatments were thoroughly mixed at the beginning of the experiment and stored in plastic bags to protect against moisture. The *G. sepium* in the MRG diet was milled to pass through a 1 cm sieve (D38, Black and Decker™, West Germany) to achieve uniformity and avoid selective feeding on the diet. Samples of all diets were taken from plastic bags at the beginning of the experiment and analysed for chemical composition.

Goats were assessed weekly throughout the experimental period for dry matter intake (DMI) and average daily weight gain (ADG), and at the end of the period also for dry matter digestibility (DMD) and overall live weight change. Individual goats were fed their respective diet at 4% DM of their body weight (with amount adjusted weekly), divided into two equal portions fed morning and afternoon, and were supplied with water *ad libitum* (mixed with the mineral premix powder, 20 g/10 L water) during the entire experimental period. Refused feed portions were collected daily, pooled in plastic bags and weighed at the end of the week, to estimate DMI of the individual goat during the study period. All goats were weighed once per week to estimate their ADG. Faeces samples were collected from the rectum of all goats, using medical rubber gloves. This was done daily for three consecutive days during week 9 and the samples in the medical rubber gloves were pooled by goat and sent for laboratory analysis.

Chemical analysis

Feed and faeces samples were analysed at Tanzania Veterinary Laboratory Agency (TVLA)-Central Veterinary Laboratory, Dar es Salaam, Tanzania. Upon arrival, all samples were oven-dried at 104°C for two hours and then milled using a hammer mill (Sogo Impact Universal Pulverizer, SS304/SS616L, Tokyo, Japan) to pass through a 1-mm screen. The concentrations of DM, ash, crude protein (CP), ether extract (EE), crude fibre (CF), neutral detergent fibre (NDF) and acid detergent fibre (ADF) in the dietary treatments were analysed using a near infrared reflectance (NIR) spectrometer (Perkin Elmer, DA 7250™) calibrated according to the manufacturer's instructions for analysis of forage and concentrate feeds. Acid-insoluble ash (AIA) content in feed and faeces samples was analysed in duplicate by ashing samples at 550°C, boiling with 3 M hydrochloric acid for 15 min and then re-ashing at 550°C (Sales and Janssens, 2003). Dry matter digestibility was calculated from AIA (g/kg DM) measured in sampled diets and faeces as: $DMD = (AIA_{(Faeces)} - AIA_{(Diet)})/AIA_{(Faeces)}$. The model 0.012CP + 0.031EE + 0.005CF + 0.014NFE was used to calculate ME in the concentrates diet and the model 0.15(0.98*DMD – 4.8) to determine ME in the forage-based diets (Bwire et al., 2003).

Data analysis

The R Program version 4.0.1 (R Core Team, 2020) was used to analyse collected data. Fixed factors included in the models were diet (3 levels), week (10 levels) and sex (2 levels). Animal (24 levels) was treated as a random factor. The ADG and DMI values determined weekly were analysed using the ANOVA type III mixed model: Y = Diet + Week + Sex + Animal + Diet*Week + Residual error. Initial live weight of goats at the start of the adaptation period, final live weight, overall live weight change (final live weight subtracted by initial live weight) and DMD were analysed using the ANOVA model: Y = Diet + Sex + Residual error. Independent variables (diet and week) and their interaction were compared using Tukey's method and differences were declared significant at p<0.05.

RESULTS

Nutritional value

Nutritional composition of the diets is shown in Table 1. The CP content was 183 g/kg DM, 73 g/kg DM and 66 g/kg DM for MRG, BG and CG respectively. The concentrate-based diet (MRG) had significantly lower DMD (38.9%) than the forage-based diets (67.7% for CG and 55.4% for BG), which did not differ significantly (Table 2). The MRG diet had the highest ME content (10.6 MJ/kg DM) among the dietary treatments, BG had the lowest (7.4 MJ/kg DM) and CG was intermediate (9.2 MJ/kg DM).

Dry matter intake and growth performance

Mean DMI was significantly affected by both diet and week (p<0.05) and was lower overall in goats fed MRG than in goats fed CG (Table 2). Goats fed MRG showed lower DMI in week 2-4, before an increase to a steady level in the remaining period. There were DMI differences between MRG and the forage-based diets during these first weeks (Figure 1). The weekly DMI trend for the forage-based diets was similar, with relatively steady intake throughout the experimental period except in week 1, when DMI was higher than in weeks 2 and 4. The ADG in growing goats were 10.7, 9.9 and 22.8 g/day for the MRG, BG and CG diets, respectively. These means were significantly affected by week and diet-week interaction, with MRG having lower ADG values than CG during weeks 1 and 2. Initial and final live weight were not significantly affected by dietary treatment during the study period. Overall live weight change was affected significantly by diets (p=0.044). Goats fed MRG showed lower overall live weight change (0.12 kg) during the experiment than goats fed CG (2.07 kg), while goats fed BG had an intermediate value (1.41 kg). Sex had no significant effect (p>0.05) on ADG, DMI, initial or final live weight, or overall live weight change.

DISCUSSION

Nutritional value of all three dietary treatments in terms of ME (Table 1) was sufficient to meet the requirement of growing indigenous goats. The ADG in goats in the present study was within the range reported by Goromela et al. (1997) and Komwihangilo et al. (2005) for Blended goats fed grass hay combined with leaf meal or concentrates. The lack of significant ADG differences between BG or CG and the concentrate-based diet shows that *B. brizantha* cv. Piatã and *C. ciliaris* can be used as supplementary feed to growing goats during the dry season, with similar daily gain effects as seen for other dry-season feeds. Other advantages are that these forage species are drought-resilient, have high biomass yield and can be conserved as hay, reducing the feed costs (Santos et al., 2013, 2018). These attributes are valuable for extensive herders during the dry season and could help them to maintain or improve the performance of their goats until the period of forage abundance in the rainy season.

The CP value in all diets was sufficient to support the nutritional requirements of growing goats as estimated by Luo et al. (2004a). The DMD of the BG diet was within the range reported by Santos et al. (2018) for *B. brizantha* cv. Piatã grass, but lower than that reported by Geremia et al. (2018). The DMD of the CG diet was higher than that reported by Goromela et al. (1997) and

Table 1. Chemical composition of the dietary treatments fed to growing blended goats.

Diet	DM	Ash	AIA	EE	CP	NDF	ADF	ME
	(g/kg)	(g/kg DM)	(g/kg DM)	(g/kg DM)	(g/kg DM)	(g/kg DM)	(g/kg DM)	MJ/kg DM
MRG	895	115	51	85	183	342	245	10.6
BG	876	67	26	15	73	533	315	7.4
CG	886	61	22	17	66	553	327	9.2

MRG = Concentrates (40% maize bran + 40% rice polish + *Gliricidia sepium* leaf meal): BG = Brachiaria (80% *Brachiaria brizantha* cv Piatã + 20% *Gliricidia sepium* leaf meal): CG = Cenchrus (80% *Cenchrus ciliaris* + 20% *Gliricidia sepium* leaf meal), DM = dry matter: AIA = acid insoluble ash: EE = ether extract: CP = crude protein NDF = neutral detergent fibre: ADF = acid detergent fibre.

Table 2. Dry matter digestibility (DMD), dry matter intake (DMI) and growth performance (mean±SE) of Blended goats during experimental period.

Parameter	MRG	BG	CG
DMI (g/day)	507.7±10.0[a]	535.0±10.0[a,b]	549.0±10.0[b]
DMD (%)	38.9±3.8[a]	55.4±3.8[b]	67.7±3.8[b]
Initial live weight (kg)	16.3±0.5	16.7±0.5	16.3±0.5
Final live weight (kg)	16.4±0.6	18.1±0.6	18.4±0.6
Overall live weight change (kg)	0.118±0.5[a]	1.410±0.5[a,b]	2.069±0.5[b]
Average daily weight gain (g/day)	10.7±5.3	9.9±5.3	22.8±5.3

MRG = Concentrates (40% maize bran + 40% rice polish + *Gliricidia sepium* leaf meal): BG = Brachiaria (80% *Brachiaria brizantha* cv Piatã + 20% *Gliricidia sepium* leaf meal): CG = Cenchrus (80% *Cenchrus ciliaris* + 20% *Gliricidia sepium* leaf meal). Means within rows with different letters are significantly different.

Komwihangilo et al. (2005) for Cenchrus-based diets. The DMD differences compared with other studies can be attributed to differences in forage stage of maturity and inclusion levels in the diets. The observed DMD differences between the concentrate-based diet (MRG) and the forage dietary treatments (BG and CG) could be explained by small particle size of the concentrates and hence short retention period in the rumen (Hummel et al., 2018). However, concentrate DMD was very low (38.9%) compared with 55% reported for other maize bran-based diets (Omar et al., 1999; Safari et al., 2009), possibly due to inclusion of rice polish in that diet. Rice polish has high AIA due to its high concentration of silica (Table 1). Dietary silica concentrations above 0.2% can skew DMD values, as the measured silica level in faeces may not accurately reflect the intestinal flow of undigested feed (Sales and Janssens, 2003; Ambreen et al., 2006).

Weekly and overall DMI were lower in goats fed MRG than in goats fed the CG diet (Table 2 and Figure 1), most likely due to experimental goats browsing in areas where *C. ciliaris* was one of the key grass species prior to the experiment. This could have affected rate of adaptation and acceptance of MRG compared with the forage-based diets. The observed DMI trend (Figure 1) was similar to that in other studies on goats switched to a high-concentrate diet (Sun et al., 2010; Serment and Giger-Reverdin, 2012). The apparent difficulty in transitioning from forage to concentrates despite *Cenchrus* hay being supplied to goats in MRG during the adaptation period could be due to the short adjustment period (two weeks) and the high level of concentrates in MRG (80%). Based on Hua et al. (2017), this could reduce rumen fibrolytic microbes in favour of non-fibrolytic microbes and lead to accumulation of lactic acid. Lactic acid accumulation is a possible cause of subacute rumen acidosis (Sun et al., 2010; Hua et al., 2017; Giger-Reverdin, 2018), which could be underlying reason for the lower DMI observed initially among goats fed MRG. Although goats fed MRG compensated for their initial daily weight loss (shown by lack of differences in ADG between the MRG and forage-based diets), their overall live weight change estimated during the entire 12 weeks was lower than in goats fed the BG and CG diets. Overall live weight gained in goats fed MRG might have been higher if the experiment had been longer, since the animals showed stable DMI towards the end of the study. However, herders only use supplementary feeds for a short period during the dry season, so prolonging the study beyond the study period would have given less relevant results. The diets based on the forage grasses *B. brizantha* cv. Piatã and *C. ciliaris* gave better DMI and overall live weight change results, indicating that both can be used as supplementary feeds in extensive livestock production system during the dry season and supporting the stated hypothesis. The cost of feeding could however be too high as the ADG was low in all treatments.

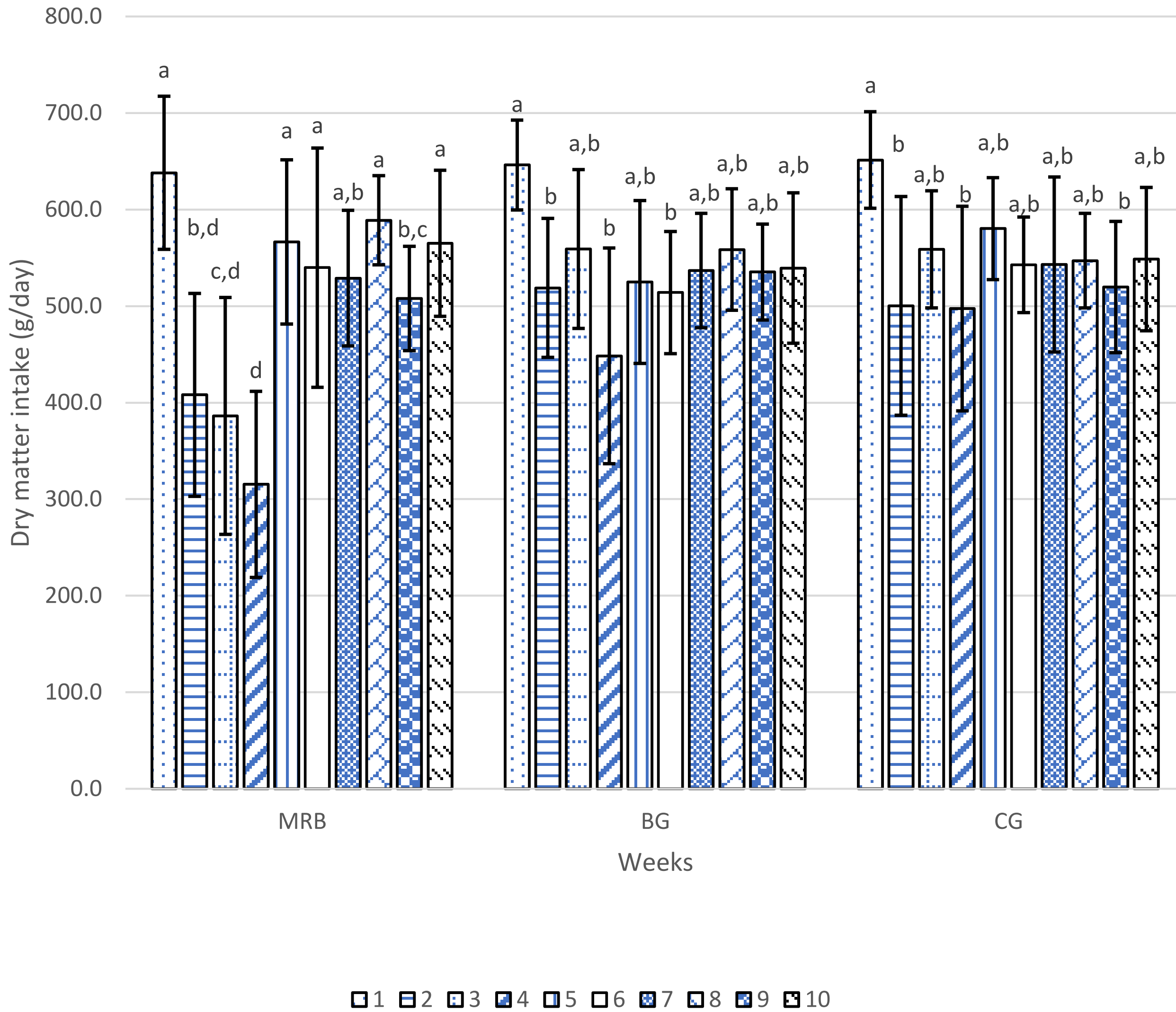

Figure 1. Dry matter intake (mean±SD) of growing Blended goats during the experimental period. Different letters (a, b, c, d) on bars within the dietary treatments and weeks indicate statistically significant differences (p<0.001). MRG = Concentrates (40% maize bran + 40% rice polish + *Gliricidia sepium* leaf meal): BG = Brachiaria (80% *Brachiaria brizantha* cv Piatã + 20% *Gliricidia sepium* leaf meal): CG = Cenchrus (80% *Cenchrus ciliaris* + 20% *Gliricidia sepium* leaf meal).

Conclusion

Forage-based diets (*B. brizantha* cv. Piatã or *C. ciliaris* combined with *Gliricidia* leaf meal) fed to previously free-browsing goats resulted in similar or higher DMI and ADG than in goats fed a concentrate-based diet (maize bran and rice bran with *Gliricidia* leaf meal). Goats fed concentrates had difficulty adapting to the change in diet, as indicated by low DMI and low overall live weight gain. Thus, an abrupt change to feeding a high-concentrate diet to previously foraging goats during the dry season will not necessarily improve their growth performance. The *B. brizantha* cv. Piatã and *C. ciliaris* forage-based diets gave equally good results and can be used as supplementary dry-season feeds for growing goats.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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